CT and X-RAY Registration

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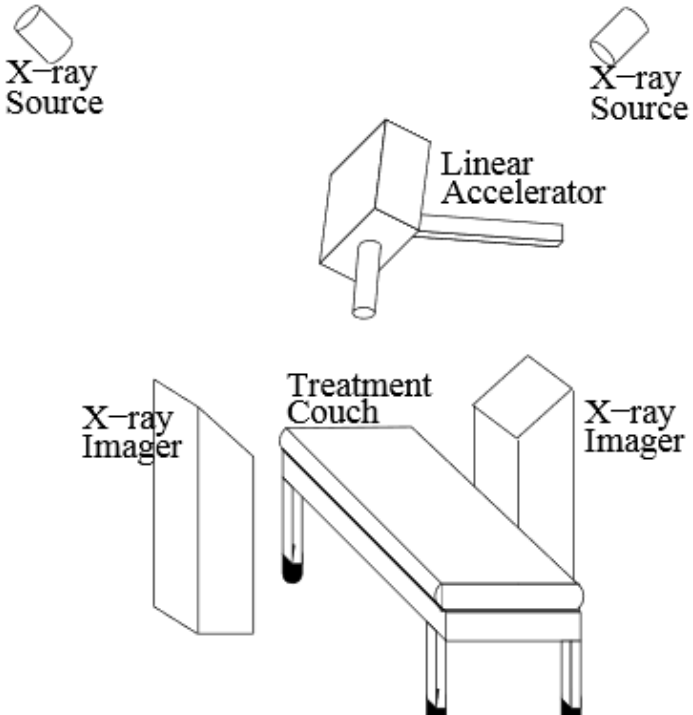
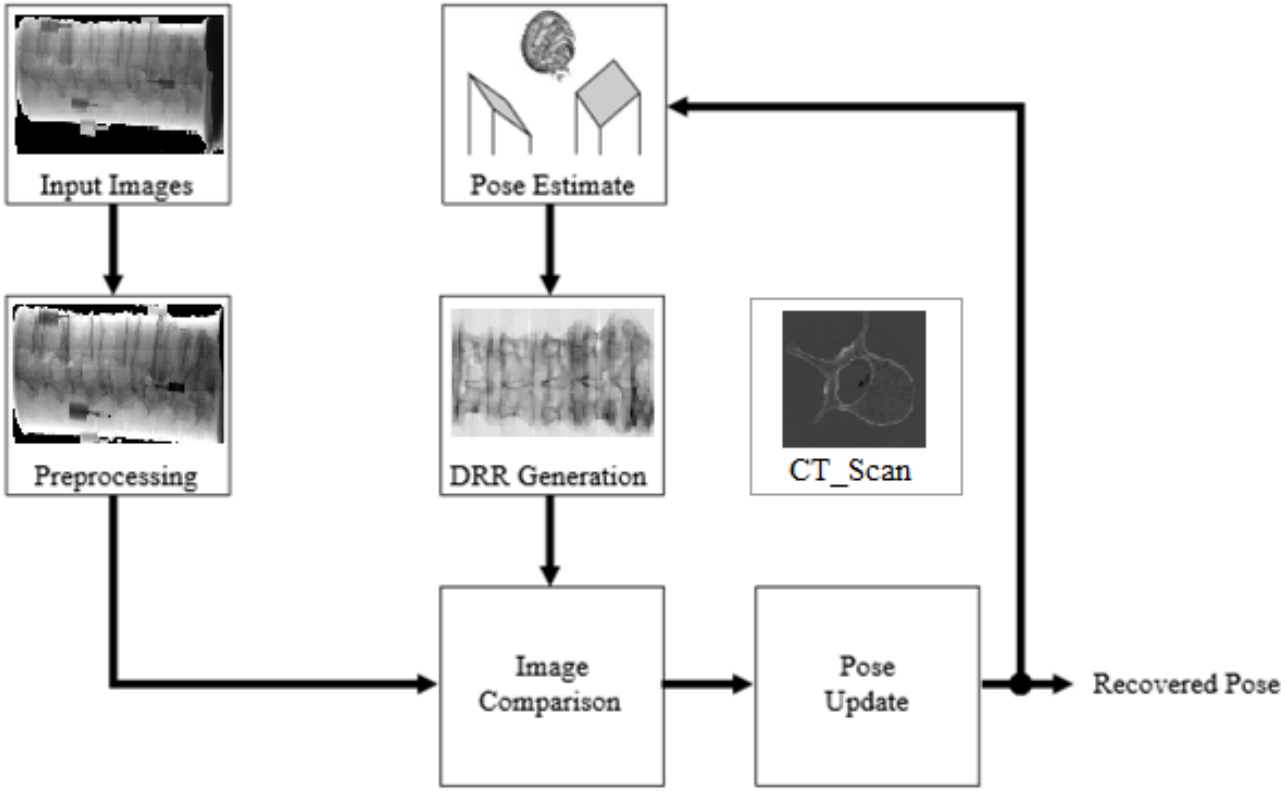
Motivation

- CT scan cannot be performed during an operation or during radiation therapy. And hence intraoperative X-Ray is registered with a Digitally Reconstructed Radiograph from pre-operative CT.
- This transformation determined is then used to align the CT correctly to assist doctors during the operation.

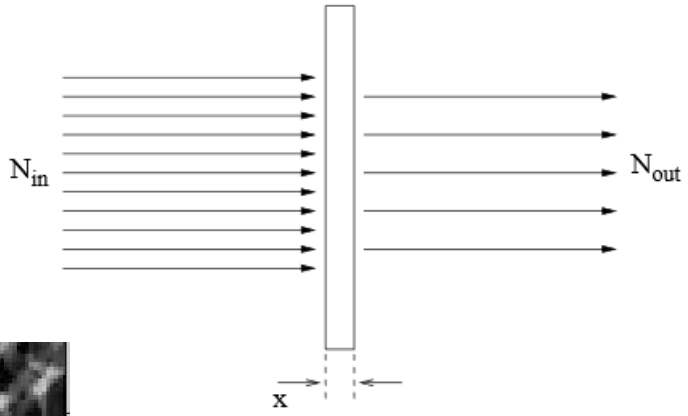


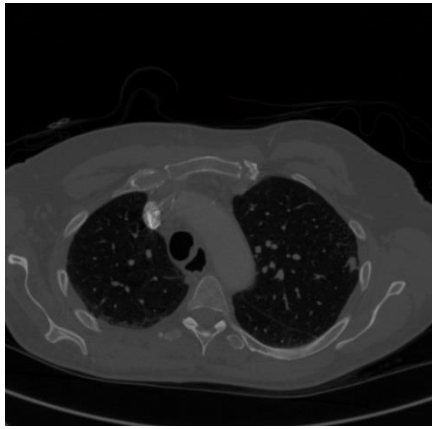
Iterative Pose Estimation

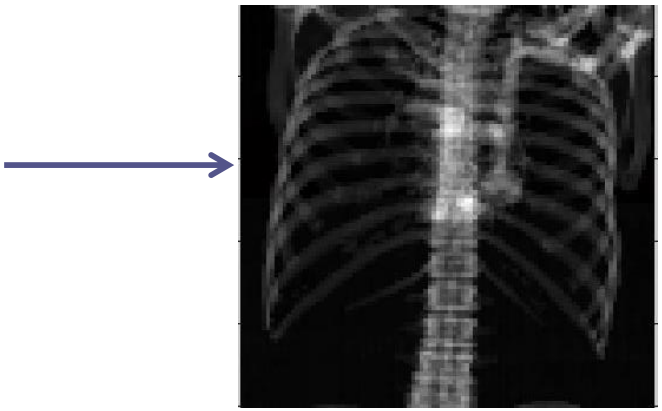


Digitally Reconstructed Radiograph

- The methodology of generating CT and X-Ray are similar.
- Hence we use Ray-Casting and take the sum of the points along a ray

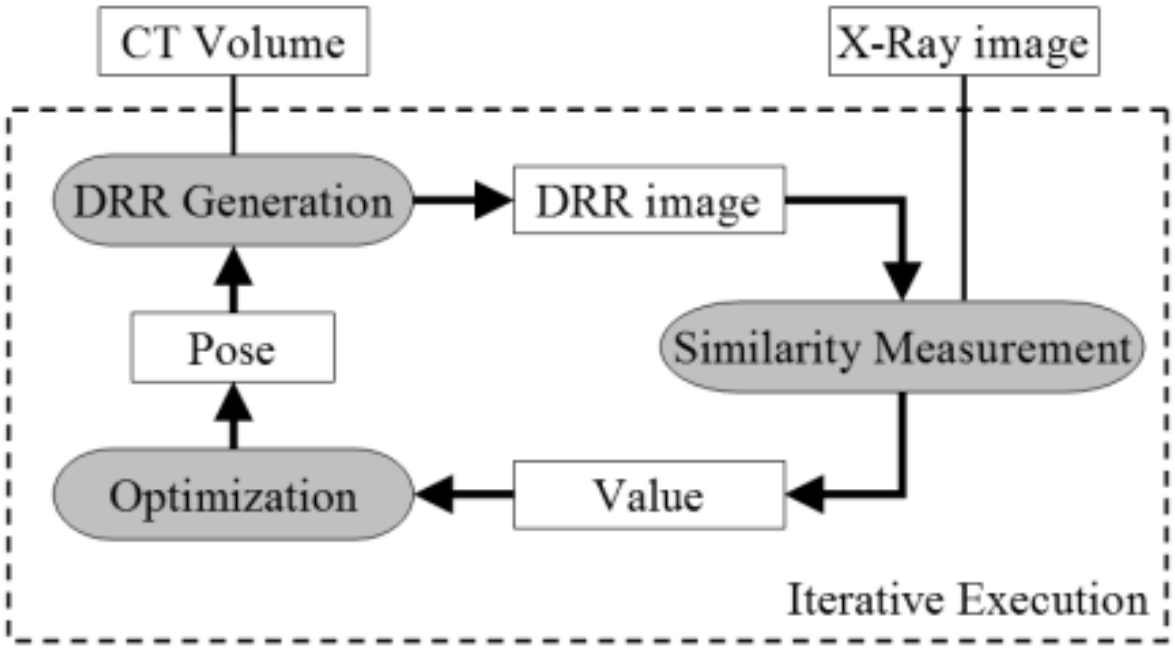






$$\int_{ray} \mu(\overline{x})ds = \ln \frac{N_{in}}{N_{out}}$$

Block Diagram



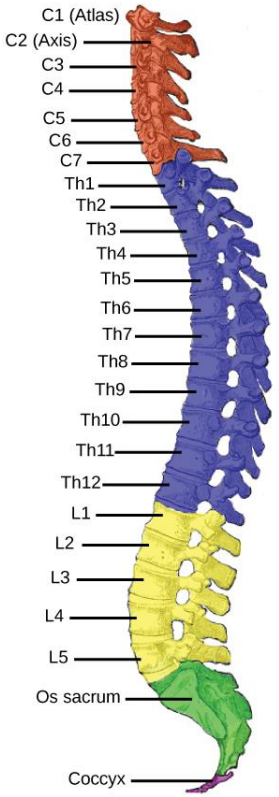
Data Set

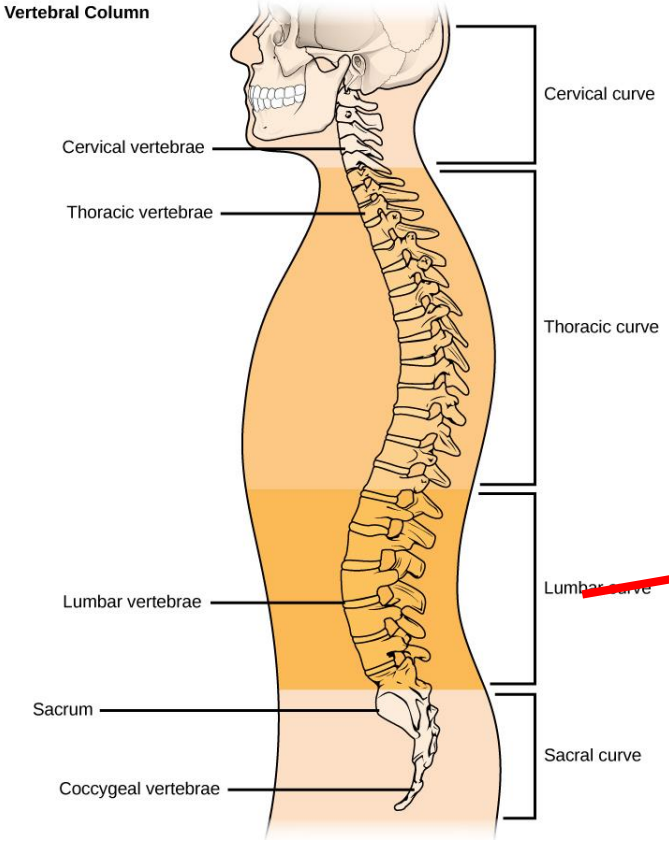
- Consisted of CT of lumbar spine for each of the 5 discs

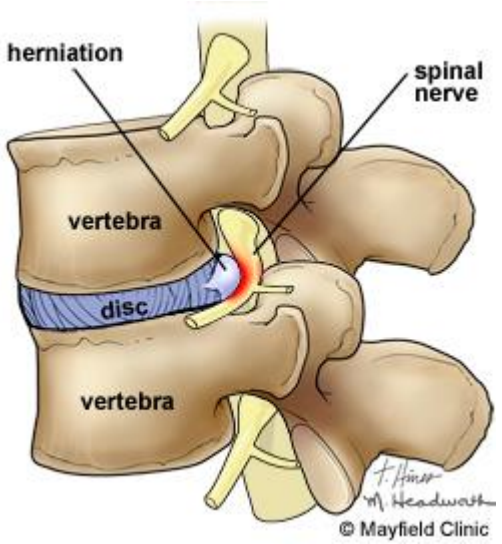
  L1, L2, L3, L4, L5

- X-Rays of Lumbar Spine with position of sensor in each case was given.

Anatomy of Spine



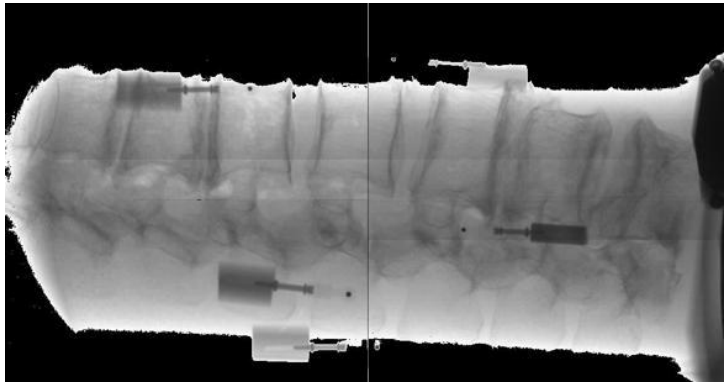




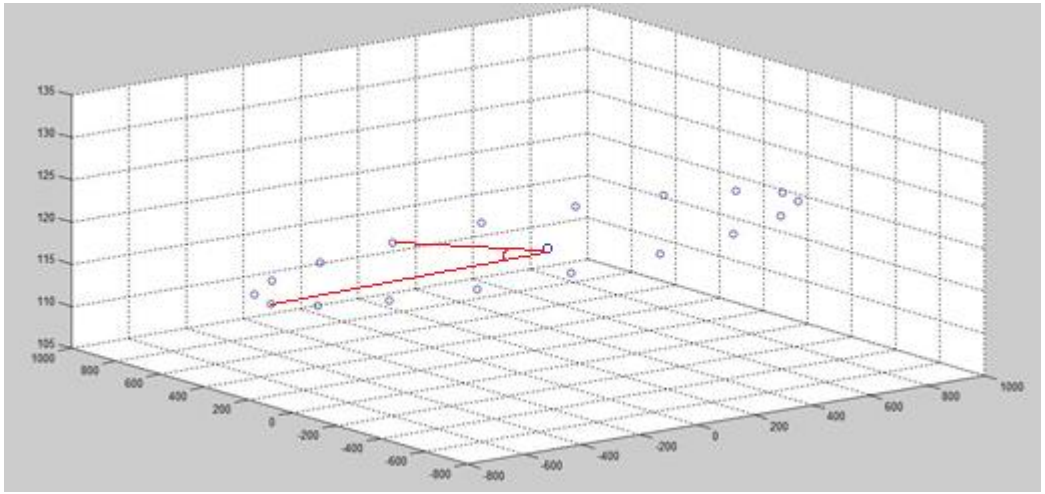
Lumbar Region
L1
L2
L3
L4
L5

X-Ray Data

- X-Rays included fiducial markers
- 18 X-rays along with the 3-D coordinates of the X-Ray source were provided



X-Ray

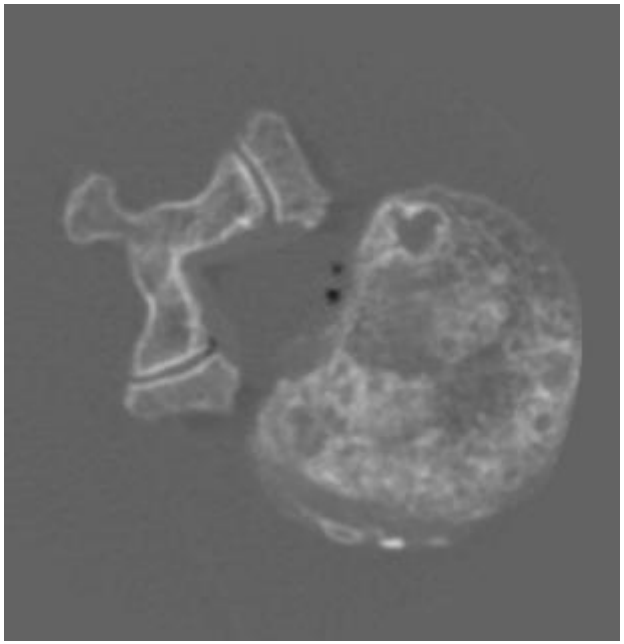


Position of sensor

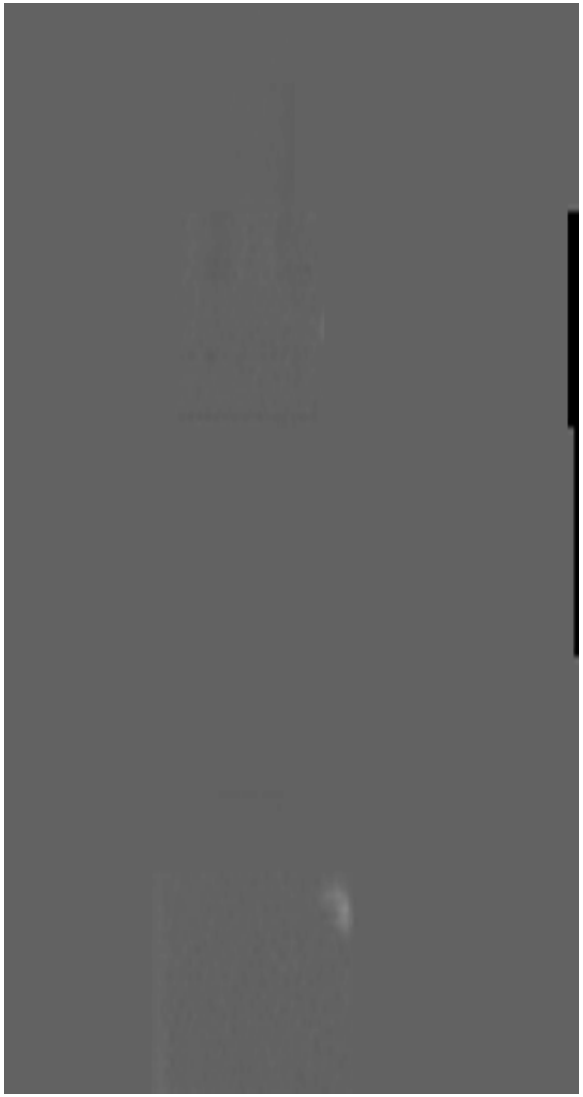
CT Data

- Combining all the 5 discs
  - Identifying the correct frame to combine with the next CT
  - Registering all the 5 CT volumes
- Issues
  - Repetition of frames in the next disc
  - Different frame size for the 5 discs

CT- Views

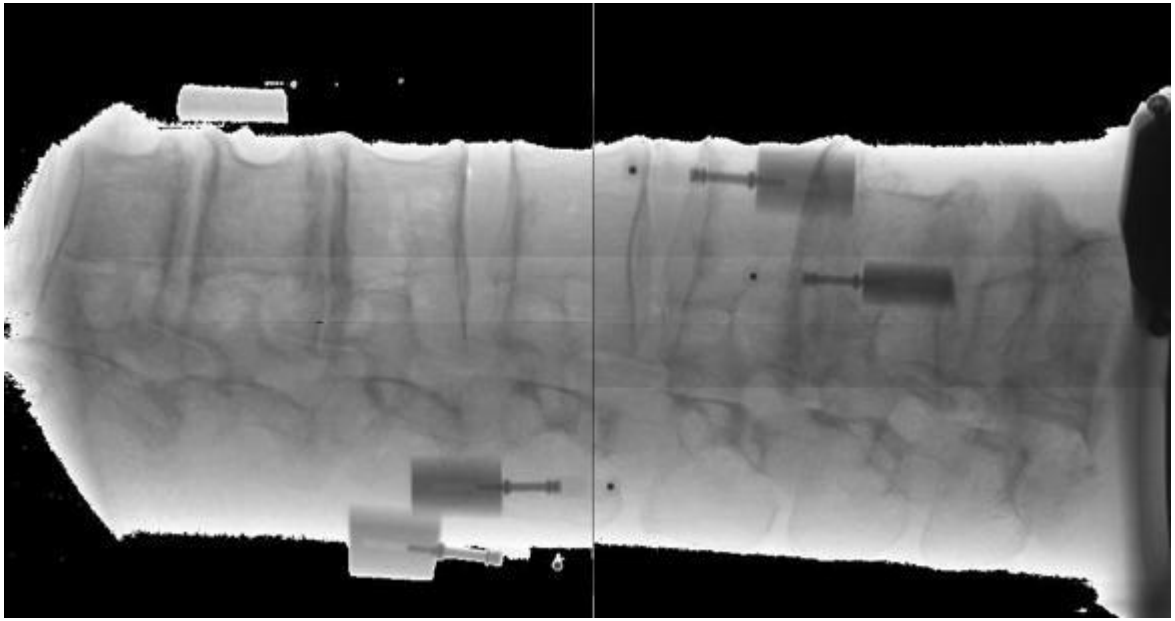


Axial



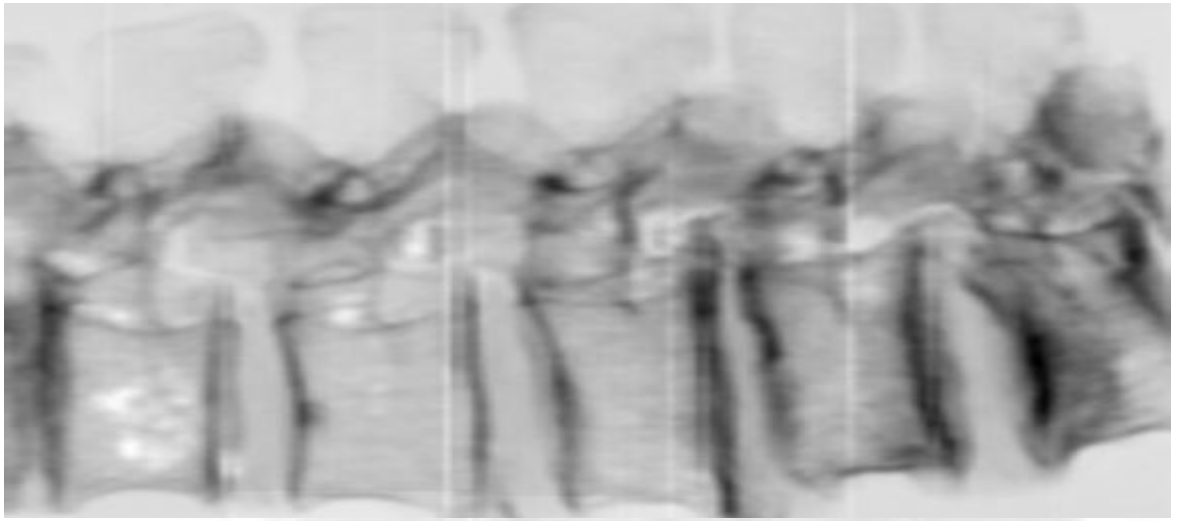
Coronal

X-Ray Data

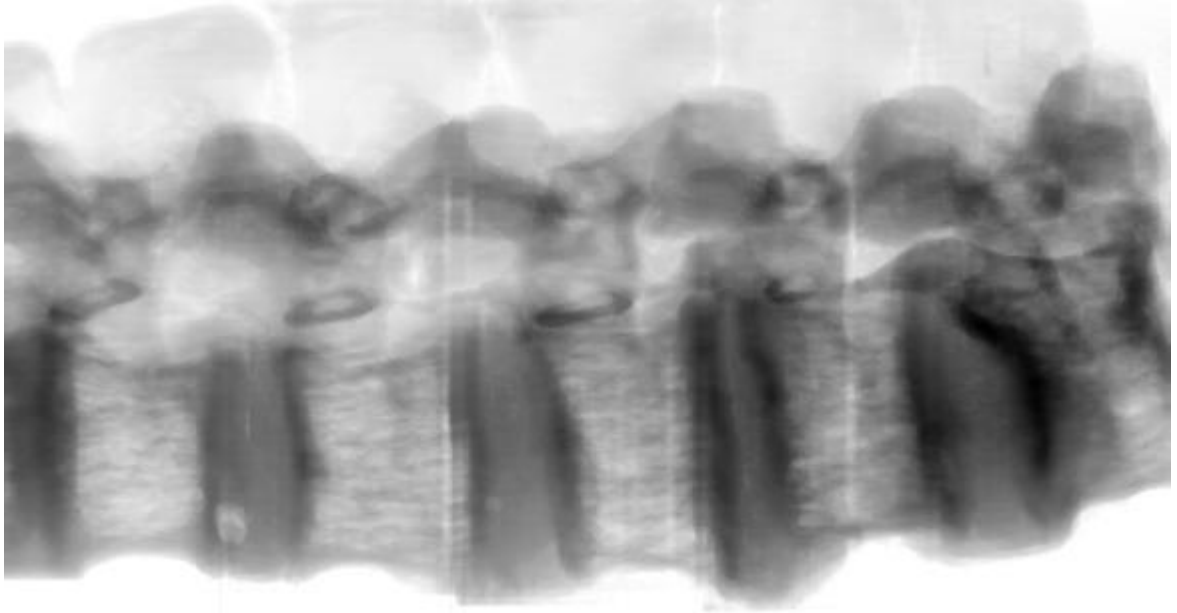


Generated DRR from CT in 360 Directions

Without Threshold



With Threshold



Identifying the angle

- Identifying the correlation with generated DRR and the given X-Ray
- To accurately predict angle
  - Tried using SSIM similarity measure
  - Tried using SSD similarity measure
- Results not satisfactory as not registered and intensity range different
- Changed the intensity range of the X-Ray and then registered with the DRR to yield acceptable results.
  - Registration using inbuilt command
  - Registration using demons

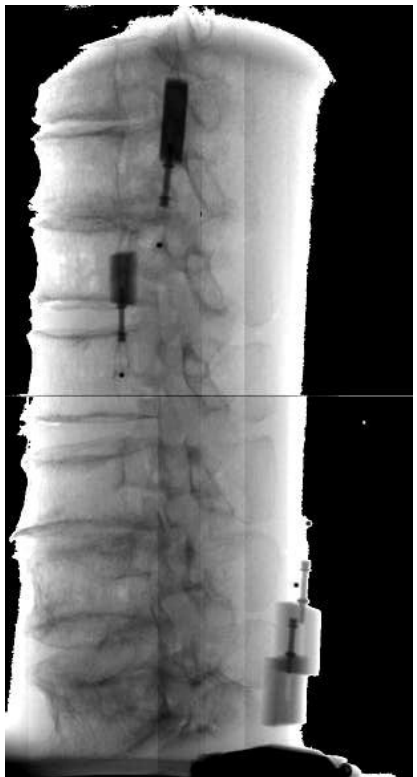
Structural Similarity Index

$$\mathrm{SSIM}(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)}$$

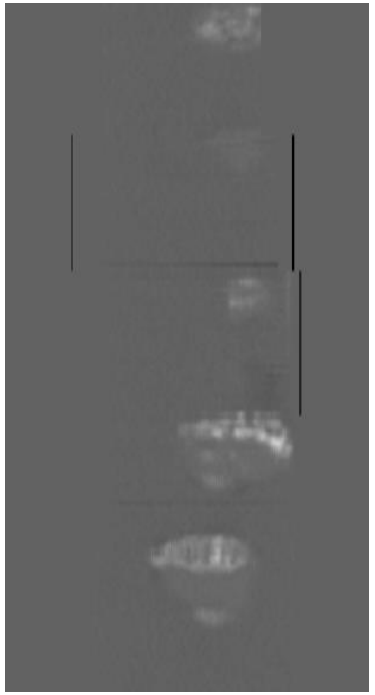
- μ_x=average of x
- μ_y=average of y
- σ_x^2=variance of x
- σ_y^2=variance of y
- σ_{xy}=covariance of x and y
- $c_1=(k_1L)^2$ $c_2=(k_2L)^2$
- C1,C2 are to stabilize the division with weak denominator
- k_1=0.01 k_2=0.03

Work Flow

Generate DRR from CT → Register to X-Ray Image to all DRRs → Determine Similarity measure → Re-orient CT accordingly



Angle



Results

- Search space reduced by upto 72%
- Need to find better registration method and similarity measure to accurately determine the angle

Reference

- “Gold Standard” 2D-3D registration, Dejan Tomaž evic, Boš tjan Likar, Franjo Pernuš- MICCAI 2002
- Iterative X-Ray/CT Registration using accelerated volume rendering- Dissertation by David A.LaRose
- Intensity Based Rigid 2D-3D Registration Algorithms for Radiation Therapy -Thesis by Wolfgang Wein –December 2003

Acknowledgements

- SSD code-Yue Wu , Tufts University
- ssim_index code -Zhou Wang, Howard Hughes Medical Institute
- Save 3d matrix as gif- Geert Van Eyndhoven
- Data Set- Dejan Tomaževic , author of Gold Standard 2D-3D registration,-MICCAI 2002
- Demons Registration Code- Dirk-Jan Kroon